

The Application of The Micro-siting technique in Tioman Island, Malaysia using the RIAM-COMPACT software

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Abstract. ASEAN (Association of Southeast Asian Nations) countries may have a huge potential for utilizing wind energy as it requires little in the way of land. Land in these countries is very fertile and is used by other alternatives, therefore reducing its conduciveness for developing solar energy. The wind resources map is widely available for Laos, Vietnam, Thailand, Cambodia and Philippines but there is not much information about other ASEAN countries. Based on meteorological data, Tioman Island was selected as the area that had the best potential for installing wind turbines in Malaysia. A more detailed study was conducted using a CFD model for unsteady flow, known as the Research Institute for Applied Mechanics, Kyushu University, COMputational Prediction of Airflow over Complex Terrain (RIAM-COMPACT) which is based on the Large-Eddy Simulation (LES) technique. Micro-siting technique is used as a tool for selecting appropriate point and an inappropriate point for locating wind turbine generators (WTGs) at Tioman Island, Malaysia. The suggested points for locating WTGs were shown based on the numerical results obtained from the calculation.

Introduction

As meteorological wind data alone is not sufficient for the accurate sighting of a large wind power project, a numerical model called the RIAM-COMPACT (Research Institute for Appplied Mechanics, Kyushu University, Computational Prediction of Airflow over Complex Terrain) is perfect for micro-siting process of evaluating the exact potential location to install a wind turbine generator (WTG). The wind synopsis technique was developed by a research group from Research Institute for Applied Mechanics, Kyushu University has the potential to resolve the above-mentioned issues. The core technology of RIAM-COMPACT was originally developed and continues to be developed at the Kyushu University Research Institute for Applied Mechanics (RIAM). [1]

An exclusive license of the core technology has been granted by Kyushu TLO Co., Ltd. to RIAM-COMPACT Co., Ltd., an IT venture corporation that was founded by the authors and other individuals and that originated at Kyushu University in 2006 (a trademark, RIAM-COMPACT, and a utility model patent were granted in 2006). In the meantime, a development consortium has been formed for the RIAM-COMPACT Natural Terrain Version software. The development consortium consists of RIAM-COMPACT Co., Ltd., West Japan Engineering Consultants, Inc. (a member of the Kyushu Electric Group), Environmental GIS Laboratory Co., Ltd., and FS Consulting Co., Ltd. The consortium has been working together to promote the software as an industry-wide standard. The RIAM-COMPACT software has been used by a large number of corporations and institutions, including J-POWER/Electric Power Development, Co., Ltd., Japan Wind Development Co., Ltd., and Eurys Energy Japan Corporation, which has the largest share of the wind power generation industry in Japan. [1]

Main features of RIAM-COMPACT software. (1) Non-stationary and non-linear CFD models simulate the wind flow that matches the wind flow that we experience every day. The wind disturbances can be understood intuitively. Non-linear models are applicable for both flat terrain and steep complex terrain. (2) Adopted an LES turbulence model that is considered more promising than a RANS turbulence model because “wind paths” and “wind disturbances” over complex terrain

can be simulated and animated. (3) Applicable for all flat and complex topographies of the world by linking to GIS (geographic information system). GIS is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. (4) Wind velocity and turbulence intensity distributions can be viewed in 3-D animations which make it easier to understand the wind pattern distributions. (5) Annual power output and utilized capacity can be calculated from the 16 wind directions dependent simulation results entered into the system. In this procedure, the correlation of the simulated results and observed data is taken into consideration. (6) Generates time series of wind data for evaluating wind load on wind turbines. Time-series data of the three compartments of the wind velocity can be output from as many as 50 selected grid points. (7) Displays distributions of wind velocity and vertical profiles of wind velocity at wind turbine sites. (8) Outputs blow up and blow down angles within the swept area of the wind turbine

There are 3 main processes involved in this software in order to simulate the wind pattern on the selected area which are (1) Pre-processing, (2) Solver and (3) Post-processing. Pre-processing is done using RC-Elevgen, RC-WindmillMaker and RC-RoughnessMaker in the RIAM-COMPACT software. RC-Elevgen is the computational grid generation software and it is capable of outputting the longitude and latitude data of the computational grid points. It accepts high-resolution elevation data (e.g: GIS elevation data, latitude and longitude ASCII elevation data). Then, specifications of wind turbine locations in decimal latitudes & longitudes are done using RC-WindmillMaker. Optionally, surface roughness supplementary service can be done using RC-RoughnessMaker based on geodetic coordinate data created by the user, land use data (surface roughness information) for the computational grid points can be obtained on-line.

As for Solver process, it is done using RC-Solver which can best be described as wind field solver. Computation of the wind field can be started in RC-Solver by specifying few computational parameters, input files and output folder.

The final process is the Post-processing which is done using RC-Scope and RC-Explorer. In RC-Scope, computational result can be visualized using the following techniques to visualize various flow properties: (i) Computational grids, (ii) Velocity vectors, (iii) isolines; isosurfaces, (iv) color shading, (v) streamlines and etc. Finally, energy generation estimation can be done using RC-Explorer. Annual energy generation (kWh), utilized capacity (%) and wind roses can be calculated from the 16 wind directions dependent simulation results entered into the systems. RC-Explorer can also output the blow down and blow up angles within the swept area of the wind turbine.

Micro-siting technique is important to locate the exact point for the optimum performance of the individual wind turbine in the wind farm. Recently, it has been reported that the utilization rates of WTGs on wind farms situated on complex terrain fall short of expectations; that is, reports of damage and breakage of the exteriors and interiors of WTGs as well as WTGs with notably low power output have surfaced. Terrain-induced turbulence is considered as the major cause of these issues. [2] The source of terrain-induced turbulence is small variations in the topographical relief in the vicinity of WTGs at which turbulence is mechanically generated. [3] The simulation results produced by RIAM-COMPACT Software can suggest which wind turbine in the wind farm are affected by the wind risks (terrain-induced turbulence).

Micro-siting using RIAM-COMPACT® at Tioman Island, Malaysia

Calculation Area. Tioman Island is a small island located 32 km off the east coast of Peninsular Malaysia in the state of Pahang,[4] and is some 39 km long and 12 km wide. The calculation areas start from Genting to Kampong Lalang and extended to Kampong Juara until Kampong Mokut in Tioman Island. The number of grid points is 50 x 50 x 40 points (approximately 100000 points). The calculation domain is 10000m x 10000m x 4044 m.

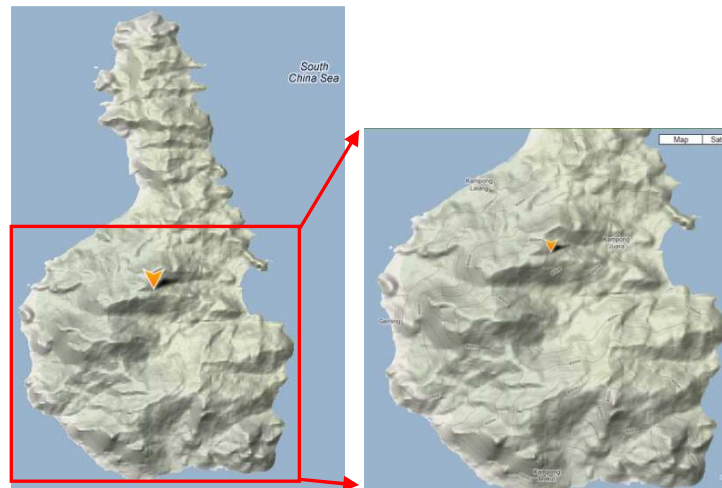


Fig. 1 Map of calculation area (from Genting – Kampung Lalang – Kampung Juara to Kampung Mokut at Tioman Island)

The high resolution elevation data for Area 3 were constructed using Geographical Information System (GIS). The shape of complex terrain was created based on 50 m Digital Elevation Model (DEM) data provided by the Geospatial Information Authority of Japan. The wind direction considers in the simulation is west-south-westerly as according to the prevailing wind direction at the area.

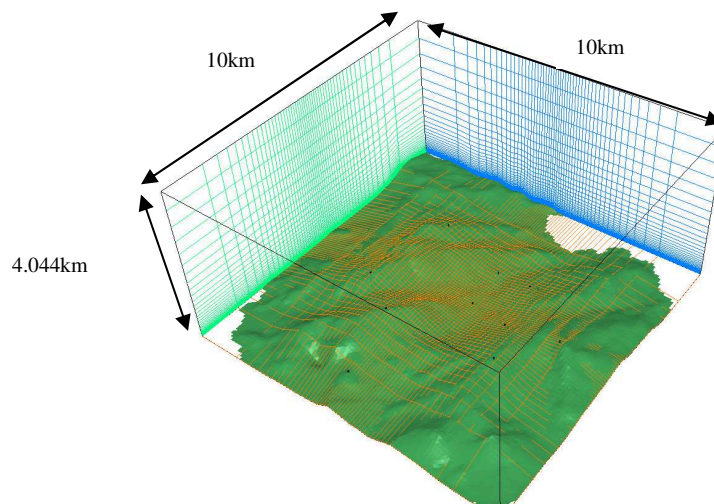


Fig. 2 Bird's eye view of the calculation area

In the RIAM-COMPACT, if the diameter of the rotor, the height of the hub, and the display color, etc. are set, and the location is specified, the 3D line chart of the Wind Turbine Generator (WTG) can be inserted into the calculation result. [2] The WTG in this study has a rotor diameter of 30m, and a hub height of 35m. The boundary conditions for the velocity field in the computational domain are as follows: 1/7 power law profile (inflow), free slip condition (top and side boundary), convective outflow condition (outflow), non-slip condition (ground).

Result and Discussion.

Appropriate Site Location for WTGs installation. There are 10 locations that have been pointed out as the potential location to install WTGS at Area 3. Out of the 10 pin-point locations, one of them cannot be considered in this discussion as the location is slightly out of calculation grid which is for WTG 4. Although 10 WTGs are set for simulation purposes, we will only focus on the further

discussion for WTG 5 and WTG 7. Besides, the explanations for both appropriate and inappropriate points will be explained in the next paragraphs.

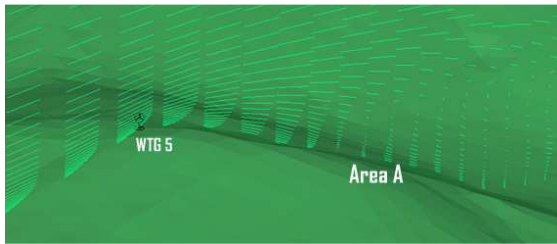


Fig. 5(a) : Velocity vectors of WTG 5 after a time period T_1

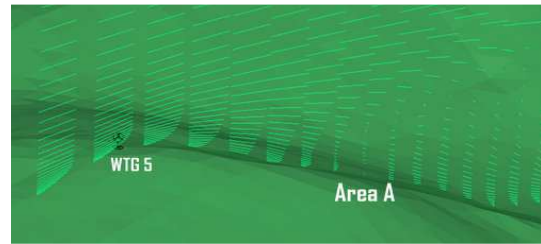


Fig. 5(b) : Velocity vectors of WTG 5 after a time period T_2

The wind velocity vectors along vertical cross-sections for WTG 5 suggest that the WTG 5 in Fig. 5 (a,b) are subject to significant influence from separated flow (terrain induced turbulence) which is generated upwind of the WTGs. In the case of WTG 5, it is understood that all rotor heights share almost the same speed distribution. In addition, a local speed-up due to geographical effect is confirmed. However, if a WTG is placed at the Area A, the result would be different. If a WTG is placed at the Area A, there exists separated flow due to the turbulent flow generated from the topographical irregularity at the Area A. Therefore, any WTG that is placed at the Area A will be influenced by the turbulent flow generated by geographical features as it is located in a lower point that shifts slightly from the hilltop. Furthermore, the wind velocity vectors at the Area A illustrates that large velocity deficits are present at multiple heights, which shows there will be an existence of large differences in the wind velocities between the lower and upper ends of the area swept by the blades. The unexpected large differences in the wind velocity across heights may induce vibrations of the WTG at the Area A and it may also cause internal damage and breakage of the WTG placed there.



Fig. 6(a) : Velocity vectors of WTG 7 after a time period T_1



Fig. 6(b) : Velocity vectors of WTG 7 after a time period T_2

The separated flow is confirmed under the rotor center in the case of WTG 7. This is due to the turbulent flow generated from the topographical irregularity behind and in front of WTG 7. That is, WTG 7 is influenced by the turbulent flow generated by geographical features as this tower is located in a lower point that shifts slightly from the hilltop. The wind velocity vectors at the WTG 7 illustrates that large velocity deficits are present at multiple heights, which shows there exists large differences in the wind velocities between the lower and upper ends of the area swept by the blades. The unexpected large differences in the wind velocity across heights may induce vibrations of the WTG 7 and may also cause internal damage and breakage of the WTG 7.

Table 1 The locations for WTGs proposed installation in Tioman Island

WTG	Location		Remarks
	Longitude	Latitude	
1	104.153	2.784	Appropriate site location
2	104.178	2.797	Inappropriate site location
3	104.153	2.77	Inappropriate site location
4	104.14	2.758	Out of grids calculation
5	104.175	2.77	Appropriate site location
6	104.185	2.778	Inappropriate site location
7	104.19	2.769	Inappropriate site location
8	104.179	2.758	Inappropriate site location
9	104.172	2.747	Inappropriate site location
10	104.188	2.746	Appropriate site location

In order to produce efficient power output, WTGs are to install in the less obstructed areas with greater wind speeds. However, great attention must be paid to the exact positions of the turbines (*micro-siting*). This is because; the cost efficiency of wind energy conversion can be critically reduced if the production of the energy is too distant from the demand center.

One more thing to take into account is that the wind blows faster at higher altitudes because of the reduced influence of drag. The increase in velocity with altitude is most dramatic near the surface and is affected by topography, surface roughness, and upwind obstacles such as trees or buildings. Typically, the increase of wind speeds with the increasing height follows a wind profile power law, which predicts that wind speed rises proportionally to the seventh root of altitude.

Conclusion

There are 6 out of the 9 WTGs location that were in the grid calculation area are placed at inappropriate site locations. Therefore, one has to take into account the inappropriate WTGs site locations before any WTGs installations are being made at the respective locations specified by latitude and longitude as mentioned in Table 1 for the optimum performance of the individual wind turbine at the wind farm. It is quite difficult to find the appropriate site location due to the complex terrain of the Tioman Island itself.

The most important idea is to find the areas of locating the WTGs at which WTGs are not influenced by (1) the turbulent flow that was generated from the topographical irregularity behind or in front of the WTGs, (2) the wind velocity does not fluctuate significantly and (3) no periodic vortex shedding phenomenon occurs at the area.

Therefore, consideration on installing the WTG at higher place is one of the options to achieve great performance of each WTG. However, more proper plan and studies on the logistical problems of sighting the wind turbine are vital as the cost efficiency can be critically reduced if the production of the energy is too distant from the demand center. Thus, typically wind turbines are most profitable at the local level with low transportation costs.

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